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(54) **Shell and tube heat pipe condenser.**

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Description

The invention relates to a Stirling engine of the type receiving heat inputs from a remote source, and particularly to a heat pipe transfer tube connected to such an engine as defined in the pre-characterising part of claim 1 and as known from US-4 523 636.

In one form of the Stirling cycle engine, a number of reciprocating pistons within cylinders are arranged in generally parallel relationship in a square cluster. The top of each cylinder is attached to a gas duct which connects to a cylindrical column having a heat exchanger, regenerator, and cooler stacked end-to-end. One means of providing heat input energy to such a Stirling engine is to employ a heat pipe which has a remotely situated evaporator which absorbs heat from some source such as solar energy, combustion flue gasses, etc., which cause the working fluid to evaporize. The vaporized working fluid is transported to the engine heat exchanger where it condenses, thus giving up its latent heat of evaporation, and then returns to the heat pipe evaporator.

In such devices according to the prior art designs, a number of shortcomings exist in the design of the heat pipe conductor which transfer the working fluid from the evaporator to the engine heat exchanger (i.e. condenser). Since the working fluid vapor and liquid phases are typically transferred within a single conduit and travel in opposite directions, the liquid working fluid can become entrained within the vapor, particularly when the engine is operating at a high power setting. Such entrainment reduces the heat transfer rate to the engine and further can prevent adequate liquid working fluid return to the heat pipe evaporator which can lead to localized areas of the evaporator "drying out" and becoming excessively heated, potentially leading to mechanical failure. Furthermore, since Stirling engine heat exchangers are very compact, condensed heat pipe working fluid tends to collect in the heat exchanger due to capillary action which represents a waste of a certain volume of the working fluid, and also decreases the useful surface area in the heat exchanger. In view of the foregoing, there is a need to provide an improved heat pipe conduit and a means for reducing the retained volume of liquid working fluid within the Stirling engine heat exchanger.

The above mentioned desirable features are achieved in accordance with this invention through an improved design heat pipe working fluid conduit assembly as defined in claim 1. The assembly features a shell and tube construction in which a flared shell joins the heat exchanger and provides a means of reducing the velocity of vaporized heat pipe working fluid as it enters the heat exchanger.This reduction in velocity tends to minimize problems of liquid entrainment within the vapor. As a further step to reduce entrainment, a separate liquid heat pipe working fluid return duct is provided within the conduit outer tube which provides isolation of the phases. A surface tension breaker is used which communicates the engine heat exchanger with the liquid return pipe as a means of reducing the volume of liquid working fluid retained by the heat exchanger.

Additional benefits and advantages of the present invention will become apparent to those skilled in the art to which this invention relates from the subsequent description of the preferred embodiments and the appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRITPION OF THE DRAWINGS

Figure 1 is a pictorial view of a Stirling engine shown driving an electrical generator and receiving input energy from a heat pipe having an evaporator heated by flue gasses.

Figure 2 is a top view of the head assembly of the Stirling engine taken in the direction of arrows 2-2 from Figure 1.

Figure 3 is a cross sectional view taken along line 3-3 of Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

With reference to Figure 1, a Stirling cycle engine generally designated by reference number 10 is shown for driving induction generator assembly 12. Stirling engine 10 is generally of the type described by U.S. Patent No. 4,481,771, issued to the assignee of this invention which is hereby incorporated by reference. Stirling engine 10 includes four parallel working cylinders 14 arranged in a square cluster, each of which communicate via arcuate hot connecting duct 16 with a cylindrical column comprising heat exchanger 18, regenerator 20, and cooler 22. Heat inputs to Stirling engine 10 are provided by a remotely mounted heat pipe evaporator assembly 24 which is heated by flue gasses from a hydrocarbon fuel burner (not shown), or any other source of heat. Evaporator assembly 24 includes evaporator 26 with internal hollow fins 28 such as described by assignee's U.S. Patent 4,523,636, which is also hereby incorporated by reference.

During operation, heat inputs to evaporator 26 cause the heat pipe working fluid, which may be, for example, sodium or other substances, to be transported through conduit assembly 32 to heat exchanger 18 which functions as the heat pipe condenser, where the heat is removed from the vaporized working fluid causing it to condense. The

condensed working fluid is thereafter returned to heat evaporator assembly 26 where the cycle continues.

Figure 2 shows details of the construction of engine head assembly 26. Heat exchanger 18 acts as the heat pipe condenser and includes a compact internal bundle 38 of relatively small diameter tubes which conduct the working fluid of the Stirling engine and isolate it from the working fluid of the heat pipe. Cylindrical shell 40 surrounds tube bundle 38 and joins with conduit assembly 32. In the region where conduit assembly 32 joins cylindrical shell 40, high velocities of vaporized working fluid are present, particularly at high power settings for engine 10. As mentioned previously, with prior art designs, problems were encountered with liquid heat pipe working fluid becoming entrained within the vapor. In accordance with this invention, several features are provided to minimize the likelihood of such entrainment. Conduit assembly 32 forms a flared shell 44 which provides an increased cross-sectional area as the conduit approaches bundle 38. The increased cross-sectional area as compared with that of the main tube section 46 forming the remainder of conduit assembly 32 causes incoming vaporized working fluid to have a reduced velocity in the area where it contacts bundle 38. Such reductions in velocity have been found to reduce liquid entrainment.

Another counter-measure employed to prevent entrainment is the use of a separate liquid return duct 48 which is disposed within main tube 46 and shell 44, and has a significantly smaller cross-sectional area than main tube 46. Liquid return duct 48 is positioned along the lowermost surface of shell 44 so that liquid collecting in that area by gravity will be guided into duct 48. Liquid return duct 48 features apertures such as a longitudinal slit 50 provided for pressure equalization between the conduits. Each of the four cylinder and column assemblies shown in Figures 1 and 2 includes its own heat pipe conduit assembly 32 constructed as previously described.

Due to the compactness and large surface area presented by tube bundle 38, there is a tendency for liquid heat pipe working fluid to collect within heat exchanger 18 due to capillary action. As a means of reducing this retained liquid volume, surface tension breakers 52 are provided in the form of strips of woven wire mesh which extends from within tube bundle 38 into liquid return conduit 48. Various mumbers of surface tension breakers could be used with preferably one for each row of tubes forming bundle 38. Surface tension breaker 52 "wicks" the liquid heat pipe fluid working fluid into liquid return conduit 48 which reduces the volume of liquid retained in that area.

As shown in Figure 2, baffles 54 are shown which shield a portion of tube bundles 38. Baffles 54 are positioned so that gas travelling through conduit assembly 32 does not directly impact tube bundle 38 but is guided to the upper portion of the tube bundle where it is permitted to flow downwardly through the tube bundle. Condensed heat pipe working fluid is allowed to fall into liquid return duct 48. Baffle 54 tends to maintain the liquid and gas phases of the heat pipe working fluid flowing in the same direction in in a continuous circulating manner thus avoiding counterflow conditions which increase the likelihood of entrainment.

Prior to starting Stirling engine 10 for the first time, contaminant gases which invariably collect within the heat pipe system need to be evacuated. Such gases such as hydrogen, oxygen, nitrogen, carbon monoxide and carbon dioxide are present from a number of sources, for example, outgasing of the heat pipe material, and the heat pipe working fluid. The presence of such gasses interferes with proper operation of the heat pipe since they can form a gas "plug" which restricts working fluid flow since the contaminant gases will collect around tube bundle 38 and thus prevent good heat conduction to the Stirling engine cycle. As a means of eliminating or reducing the presence of such contamination gasses, Stirling engine 10 incorporates getter 56 which is affixed to cylindrical shell 40 in a fluid-tight manner. Getter shell 58 forms an internal compartment which is filled with chemical degassers such as calcium and lanthanum. The contents of shell 58 are retained in place by wire mesh 60. A heated collar 62 is provided which surround shell 58 and heats the contents of the getter 56 to a temperature preferably between 600 and 800 degrees C. to enhance its gas absorption characteristics. The phantom line illustration of heated collar 62 in Figure 2 shows its installation around getter shell 58. Getter 56 is positioned in the upper portion of heat exchanger 18 where contaminant gases tend to collect. The contaminant gases forming in the area of heat exchanger 18 interfere with the transfer of heated working fluid from heat pipe evaporator 26, thus preventing it from being heated directly by the working fluid. By employing the external heat source of collar 62, getter 56 can be used to immediately absorb the contaminant gases, allowing the heat pipe working fluid to reach heat exchanger 18. After initial operation of getter 56 and heated collar 62, the heated collar can be removed from the engine since getter 56 will thereafter be heated sufficiently by the heat pipe working fluid due to the relatively small quantities of contaminant gases which tend to collect after inital startup of the engine 10 and the heat pipe. An additional internal getter 64 is provided directly in the flow path of the vapor such that entrained

impurities are forced to flow through the internal getter.

Claims

1. A heat pipe working fluid conduit assembly for transferring vaporized working fluid from a heat pipe evaporator (24) to a heat exchanger (18) of a Stirling engine (10) and for returning liquid working fluid from said heat exchanger (18) to said evaporator (24) comprising a conduit (32) communicating with said evaporator (24) and said heat exchanger (18) for transferring said vaporized working fluid, characterised in that said conduit (32) has a flared shell (44) joining said heat exchanger (18) whereby the cross-sectional area of said conduit (32) increases as said conduit (32) approaches said heat exchanger (18), and a duct (48) has been disposed inside said conduit (32) for receiving said liquid working fluid from said heat exchanger (18) and returning said liquid to said evaporator (24).

2. A heat pipe working fluid conduit assembly according to claim 1 wherein said duct (48) has an aperture (50) along its length to equalize pressure between said conduit (32) and said duct (48).

3. A heat pipe working fluid conduit assembly according to claim 2 wherein said aperture (50) is a longitudinal slit.

4. A heat pipe working fluid conduit assembly according to any preceding claim further comprising at least one surface tension breaker (52) communicating said heat exchanger (18) with said duct (48) for wicking said liquid working fluid from said heat exchanger (18) to said duct (48).

5. A heat pipe working fluid conduit assembly according to any preceding claim wherein said Stirling engine (10) comprises a plurality of cylinders (14) each having an adjacent column formed by a cooler (22), regenerator (20), and said heat exchanger (18), with a connecting duct (16) communicating said column with said cylinder (14).

6. A heat pipe working fluid conduit assembly according to any preceding claim wherein said heat exchanger (18) comprises a plurality of tubes (38) with said heat pipe working fluid condensing onto the outside of said tubes.

7. A heat pipe working fluid conduit assembly according to any preceding claim wherein said duct (48) has an inlet disposed in said shell (44) and positioned at a lower area of said shell (44) for receiving condensed liquid heat pipe working fluid.

8. A heat pipe working fluid conduit assembly according to any preceding claim further comprising a baffle (54) partially shielding said heat exchanger (18) for guiding said vaporized working fluid to an upper portion of said heat exchanger (18) whereby said vaporized working fluid is directed to flow downwardly through said heat exchanger (18) and said liquid working fluid condensing within said heat exchanger (18) and falling into said duct (48).

9. A heat pipe working fluid conduit assembly according to any preceding claim wherein said engine (10) is of the type having a plurality of cylinders (14) each having an adjacent cylindrical shell (40) enclosing said heat exchanger (18) and joined by said conduit (32).

Patentansprüche

1. Leitungseinheit für ein Wärmerohrarbeitsmittel zur Übertragung des verdampften Arbeitsmittels von einem Wärmerohrverdampfer (24) zu einem Wärmeaustauscher (18) einer Stirling-Maschine (10) und zum Zurückführen des flüssigen Arbeitsmittels vom Wärmetauscher (18) zum Verdampfer (24), mit einer Leitung (32), die mit dem Verdampfer (24) und dem Wärmetauscher (18) in Verbindung steht und zur Überführung des verdampften Arbeitsmittels dient, dadurch gekennzeichnet, daß die Leitung (32) ein konisch erweitertes Gehäuse (44) aufweist, das mit dem Wärmetauscher (18) verbunden ist, so daß der Querschnittsbereich der Leitung (32) bei Annäherung des Wärmetauschers (18) durch die Leitung (32) ansteigt, und daß ein Kanal (48) zur Aufnahme des flüssigen Arbeitsmittels vom Wärmetauscher (18) und zur Zurückführung der Flüssigkeit zum Verdampfer (24) innerhalb der Leitung (32) angeordnet ist.

2. Leitungseinheit nach Anspruch 1, bei der der Kanal (48) über seine Länge eine Öffnung (50) aufweist, um den Druck zwischen der Leitung (32) und dem Kanal (48) auszugleichen.

3. Leitungseinheit nach Anspruch 2, bei der die Öffnung (50) ein Längsschlitz ist.

4. Leitungseinheit nach einem der vorangehenden Ansprüche, die desweiteren mindestens einen Oberflächenspannungsbrecher (52) umfaßt, der den Wärmetauscher (18) mit dem Kanal (48) verbindet, um das flüssige Arbeitsmittel vom Wärmetauscher (18) zum Kanal (48) zu führen.

5. Leitungseinheit nach einem der vorangehenden Ansprüche, bei der die Stirling-Maschine (10) eine Vielzahl von Zylindern (14) umfaßt, die jeweils eine benachbarte Säule aufweisen, die durch einen Kühler (22), Regenerator (20) und den Wärmetauscher (18) gebildet ist, wobei ein Verbindungskanal (16) die Säule mit dem Zylinder (14) verbindet.

6. Leitungseinheit nach einem der vorangehenden Ansprüche, bei der der Wärmetauscher (18) eine Vielzahl von Rohren (38) aufweist, wobei das Arbeitsmittel des Wärmerohres auf der Außenseite der Rohre kondensiert.

7. Leitungseinheit nach einem der vorangehenden Ansprüche, bei der Kanal (48) einen im Gehäuse (44) angeordneten Einlaß aufweist, der an einem unteren Bereich des Gehäuses (44) angeordnet ist, um kondensiertes flüssiges Arbeitsmittel des Wärmerohres aufzunehmen.

8. Leitungseinheit nach einem der vorangehenden Ansprüche, die desweiteren eine Trennwand (54) umfaßt, die den Wärmetauscher (18) teilweise abschirmt, um das verdampfte Arbeitsmittel zu einem oberen Abschnitt des Wärmetauschers (18) zu führen, wobei das verdampfte Arbeitsmittel so geleitet wird, daß es durch den Wärmetauscher (18) nach unten strömt, und wobei das flüssige Arbeitsmittel innerhalb des Wärmetauschers (18) kondensiert und in den Kanal (48) fällt.

9. Leitungseinheit nach einem der vorangehenden Ansprüche, bei der die Stirling-Maschine (10) eine Vielzahl von Zylindern (14) besitzt, die jeweils ein benachbartes zylindrisches Gehäuse (40) aufweisen, das den Wärmetauscher (18) umgibt und mit der Leitung (32) verbunden ist.

Revendications

1. Ensemble à conduit de fluide de travail à caloduc destiné à transférer un fluide de travail vaporisé d'un évaporateur (24) à caloduc à un échangeur de chaleur (18) d'un moteur (10) à cycle de Stirling, et à renvoyer le fluide de travail à l'état liquide de l'échangeur de chaleur (18) à l'évaporateur (24), comprenant un conduit (32) communiquant avec l'évaporateur (24) et l'échangeur de chaleur (18) et destiné à transférer le fluide de travail vaporisé, caractérisé en ce que le conduit (32) a une coquille évasée (44) se raccordant à l'échangeur de chaleur (18) d'une manière telle que la section du conduit (32) augmente lorsque le conduit (32) se rapproche de l'échangeur de chaleur (18), et un tube (48) a été placé à l'intérieur du conduit (32) afin qu'il reçoive le fluide de travail à l'état liquide provenant de l'échangeur de chaleur (18) et renvoie le liquide à l'évaporateur (24).

2. Ensemble à conduit de fluide de travail à caloduc selon la revendication 1, dans lequel le tube (48) a une ouverture (50) formée suivant sa longueur et destinée à égaliser la pression entre le conduit (32) et le tube (48).

3. Ensemble à conduit de fluide de travail à caloduc selon la revendication 2, dans lequel l'ouverture (50) est une fente longitudinale.

4. Ensemble à conduit de fluide de travail à caloduc selon l'une quelconque des revendications précédentes, comprenant en outre au moins un organe (52) de réduction de tension superficielle faisant communiquer l'échangeur de chaleur (18) avec le tube (48) afin que le fluide de travail à l'état liquide soit déplacé par effet de mèche de l'échangeur de chaleur (18) vers le tube (48).

5. Ensemble à conduit de fluide de travail à caloduc selon l'une quelconque des revendications précédentes, dans lequel le moteur (10) à cycle de Stirling comprend plusieurs cylindres (14) ayant chacun une colonne adjacente formée par un refroidisseur (22), un régénérateur (20) et l'échangeur de chaleur (18), un tube de raccordement (16) faisant communiquer la colonne avec le cylindre (14).

6. Ensemble à conduit de fluide de travail à caloduc selon l'une quelconque des revendications précédentes, dans lequel l'échangeur de chaleur (18) comporte plusieurs tuyaux (38), le fluide de travail du caloduc se condensant à l'extérieur des tuyaux.

7. Ensemble à conduit de fluide de travail à caloduc selon l'une quelconque des revendications précédentes, dans lequel le tube (48) a une entrée placée dans l'enveloppe (44) et disposée dans une région inférieure de l'enveloppe (44) afin qu'elle reçoive le fluide de travail

condensé à l'état liquide du caloduc.

8. Ensemble à conduit de fluide de travail à caloduc selon l'une quelconque des revendications précédentes, comprenant en outre un déflecteur (54) qui protège partiellement l'échangeur de chaleur (18) afin qu'il guide le fluide vaporisé de travail vers une partie supérieure de l'échangeur de chaleur (18), si bien que le fluide vaporisé de travail s'écoute vers le bas dans l'échangeur de chaleur (18), le fluide de travail à l'état liquide se condensant dans l'échangeur de chaleur (18) et tombant dans le tube (48).

9. Ensemble à conduit de fluide de travail à caloduc selon l'une quelconque des revendications précédentes, dans lequel le moteur (10) est du type ayant plusieurs cylindres (14) qui ont chacun une enveloppe cylindrique adjacente (40) qui entoure l'échangeur de chaleur (18) et qui est raccordée par le conduit (32).

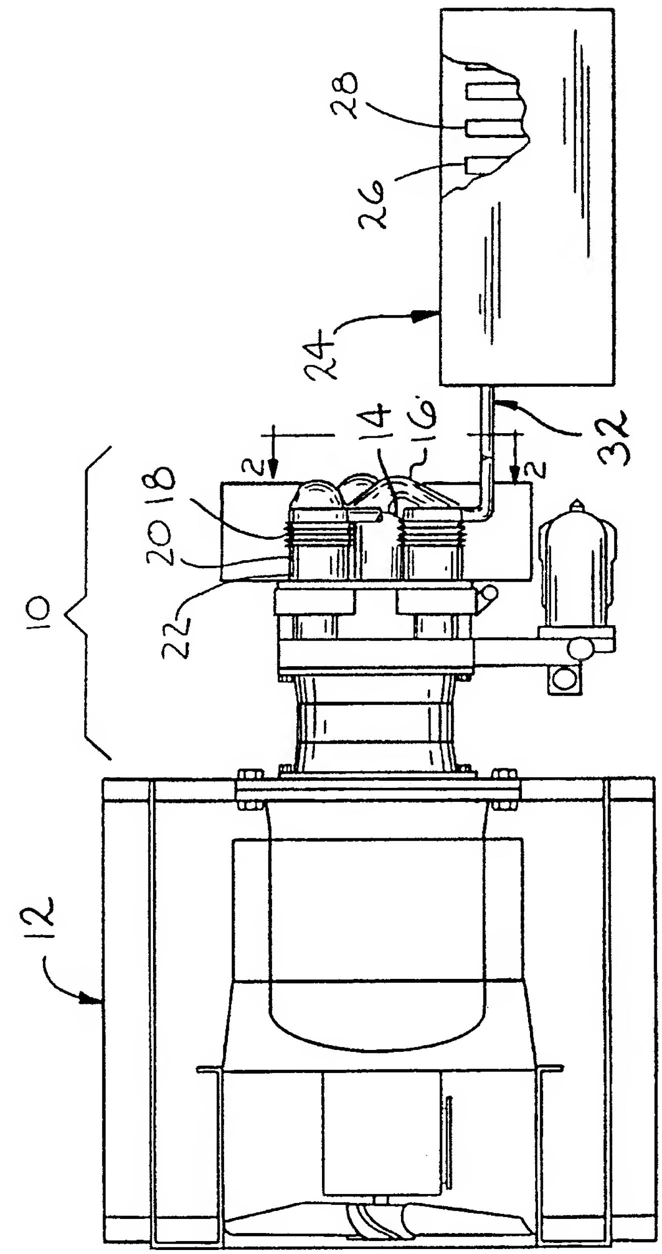

FIG. 1

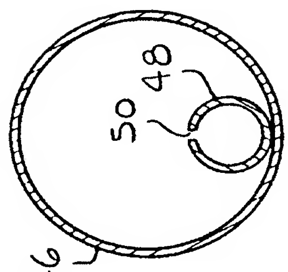
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FIG. 3

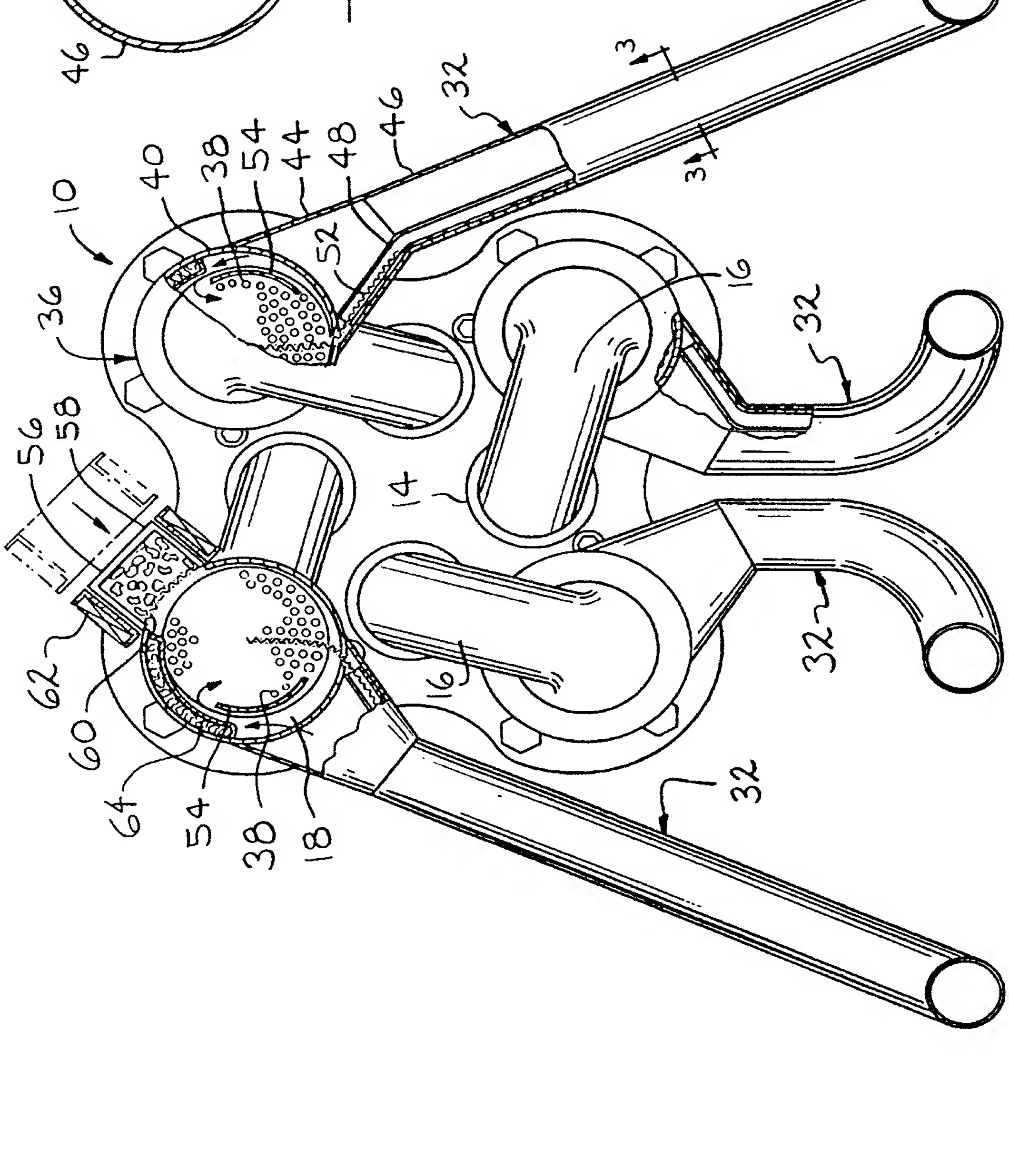
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FIG. 2